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Research Article

Association of poverty with higher risk of fragility fractures in postmenopausal Caucasian Spanish women

Marlene García-Quintana[1], Maria Jesús Gómez de Tejada-Romero[2], Pino Quintana-Montesdeoca[3], Diego Hernández-Hernández[4], Manuel Sosa-Henríquez[1,4,*]

[1]University of Las Palmas de Gran Canaria, University Institute of Biomedical and Sanitary Investigations (IUIBMS), Las Palmas de Gran Canaria, Canary Islands, Spain

[2]University of Seville, Department of Medicine, Seville, Spain

[3]University of Las Palmas de Gran canaria, Department of Mathematics, Las Palmas de Gran Canaria, Canary Islands, Spain

[4]Hospital University Insular, Bone Metabolic Unit, Las Palmas de Gran Canaria. Canary Islands, Spain

*Author for correspondence:
Email: manuel.sosa@ulpgc.es

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Abstract

Background: Poverty is associated with a great number of diseases, but the prevalence of quality alterations of the bone, measured by trabecular bone score and quantitative ultrasounds and its association to osteoporosis and fragility fractures are less well known.

Objective: To evaluate the associations between poverty, bone quality and fragility fractures in a population of Southern European postmenopausal women.

Method: Cross-sectional study was carried out in 762 postmenopausal Caucasian Spanish women. The socio-economic status of the participants was determined after a personal interview, according to the criteria of the Spanish Institute of Statistics. Participants were divided into two socio-economic levels: low (poverty) and medium or high socioeconomic level. The study protocol included a health questionnaire, a complete physical examination, lateral radiograph of the dorsal and lumbar spine and measurement of bone mineral density (BMD) at the lumbar spine (L2-L4) and proximal femur, trabecular bone score (TBS) at the lumbar spine and Quantitative ultrasound**s** at the heel.

Results: Low socio-economic status was associated with lower values of TBS at the lumbar spine and also lower values of QUS (QUI and BUA) after adjusting by age and BMI. Poverty was also associated with a higher prevalence of all type of fragility fractures: vertebral, hip fracture and some non-vertebral: Colles´, Humerus and tibia but not to ribs fractures.

Conclusions: Poor postmenopausal Caucasian Spanish women have a high prevalence of osteoporosis and osteoporotic fractures. Poverty was associated with older age and higher BMI and lower values of TBS and QUS could reflect a worse bone quality.

Keywords: Poverty, Bone quality, Quantitative ultrasound, Trabecular bone score, Fragility fractures, Postmenopausal, Caucasian Spanish women

Introduction

Osteoporosis is a common bone disease characterized by low bone mass and altered bone microarchitecture, resulting in decreased bone strength with an increased risk of fractures [1]. It has been well documented that dual-energy X-ray absorptiometry (DXA) provides an accurate estimate of BMD [6] because as T-scores decrease, the relative risk for fracture increases [2]. This principle makes the T-score an effective means of identifying those individuals at increased fracture risk and offers a cut point that allows for a diagnosis of osteoporosis [3,4] However, this does not always translate into an accurate estimate of future fracture risk [5].

It is, moreover, now well established that BMD is not the only characteristic of bone that determines its strength and fragility [6] and, therefore, must be considered when deciding upon therapy to prevent new or further osteoporotic fractures. Other factors that influence both bone strength and fracture risk include such bone characteristics as the bone macro-geometry, bone mineralization, and bone turnover, which have been globally referred to as "bone quality"[7-9]. Another key determinant of bone strength is its microarchitecture, the importance of which has been increasingly appreciated in recent years [10]. This acknowledgement has led to the recognition that evaluating bone micro-architecture [11] might significantly enhance the accuracy of bone strength evaluations and, consequently, also of fracture risk [11,12].

Trabecular bone score (TBS) represents a new texture parameter coming from pixel gray-level variations in DXA images at lumbar spine. It has been proposed to reflect bone microarchitecture status and bone quality and cumulating evidences suggest that it may contribute to fracture risk assessment [10,12,13]

Quantitative ultrasound (QUS), as measured by broadband ultrasound attenuation (BUA, in decibels per megahertz) and speed of sound (meters per second), has been suggested to be reflective of both bone density and bone structure [8,14,15]. Many studies have shown that QUS measurements, particularly those measured at the heel, can predict fracture risk as well, and independent of BMD [16-19].

We have previously carried out a study in which we observed that poor women had a greater risk of suffering fragility fractures [20]. Our initial literature search produced no studies measuring bone quality by TBS or QUS, leading to our carrying out this work.

Material and Methods

Subjects

Between January 2022 and January 2023, 762 consecutive first time outpatient postmenopausal Caucasian women at a Metabolic Bone Clinic in the Spanish public health system (Canary Islands; Latitude/Longitude 28 06' N, 15o 24'W) as outpatients were included in this study. The inclusion criteria were as follows: age between 50 and 90 years, being born and resident in the Canary Islands. Postmenopausal women were defined as those who had had their last menstrual period at least one year previously, in accordance with the clinical definition of the World Health Organization [21].

All patients were informed about the aims of the study and having given written informed consent. Medications likely to influence skeletal metabolism or the interpretation of results (i.e. thiazides, hormonal replacement therapy) were recorded. Women treated with anti-osteoporosis medications including calcium and vitamin D supplements and those with known malabsorption, cancer or other serious diseases were excluded from the study. The participants were referred to by Gynaecology, Endocrinology and Internal Medicine Services after ruling out secondary causes of osteoporosis. The younger women had suffered a bilateral oophorectomy without malignancy. The study was conducted following the Principles of the Helsinki Declaration [22]. The Ethics Committee of the Insular University Hospital of Gran Canaria approved the study.

Methods

A complete physical examination was performed. Height and weight were measured to obtain the body-mass index (BMI) of each subject. The socioeconomic status of the participants was stated after a personal interview, following the criteria of the Spanish Institute of Statistics, who establishes the presence of poverty with an annual income lower than 8,871 Euros in a one member family [23]. Actual calcium intake was calculated using a short food frequency questionnaire [24], previously used in other studies [25,26].

QUS measurements

All subjects underwent calcaneus QUS measurement. This was performed using the Sahara® Clinical sonometer (Hologic, Bedford, MA). The system consists of two unfocused transducers mounted coaxially on a monitor caliper. One transducer acts as the transmitter and the other as a receiver. The transducers are acoustically coupled to the heel using soft rubber pads and an oil-based coupling gel. The Sahara device measures both broadband ultrasound attenuation (BUA) and speed of sound (SOS) at a fixed region of interest in the mid-calcaneus, and the BUA and SOS results are combined to provide an estimate of the quantitative ultrasound index (QUI).

For all QUS measurements, the corresponding T scores were calculated as TS = (QUS - lP)/rP, where QUS represents each QUS measurement and lP and rP represent the mean and standard deviation, respectively, corresponding to the peak bone mass in healthy Spanish women, previously established for the Spanish population by our working group in an evaluation of 1,145 healthy women, aged 20–99 [27].

Quality assurance

Additional quality controls were done every morning for the QUS and DXA devices, according to the guidelines of the manufacturers, to verify the stability of the respective systems. The quality-control data of both devices (QUS and DXA) did not show any shift or drift during the entire study period. Consequently, the devices included in this study were characterized as stable.

We chose the Sahara Calcaneus ultrasonograph because we have used it in several previous multicentre clinical studies with the research group on ultrasound and bone metabolism (GIUMO), having established the normality values for the Spanish population as well as the precision and accuracy of this test [27] and being used in some other studies [48,49].

Determination of bone mineral density and diagnosis of fractures

The BMD was measured in all patients in the lumbar spine (L2–L4) and in the proximal femur (sub-regions: femoral neck, total hip, trochanter and intertrochanter) using dual X-ray absorptiometry with a Hologic® 4500 apparatus. The T-score was obtained using normality values established in the Canarian population [28]. The coefficient of variation (CV) has been established in 1% for lumbar spine and 1.5% for femoral neck [29].

Trabecular bone score

TBS was calculated from the same LS DXA scan as BMD using TBS iNsight Software (version 2.2.0; Medimaps, Geneva, Switzerland). We excluded women with body mass index (BMI) outside the range 15-37 kg/m^2 as recommended by the TBS manufacturer [30].

We have chosen the TBS INsight software because it was the one used by the working group to establish normality values in the Spanish population [12].

Fracture diagnosis

To establish the diagnosis of fragility fractures, all the patients were clinically studied and all the fractures. To detect vertebral fractures, X-rays in the lumbar and dorsal spine were carried out in all patients; the diagnosis of vertebral fractures was established after applying the Genant criteria for vertebral deformities [31]. The data on non-vertebral fractures were gathered from information provided by the patients, confirmed by a review of their clinical history, and documented through X-ray or a report from a specialist.

Statistical analysis

The categorical variables were summarized as percentages and the continuous ones as means and standard deviations when the data followed a normal distribution or medians and interquartile range (IQR) when they did not. The percentages were compared using the chi-square test, the means by the t-test and the medians by the Wilcoxon test. For QUS and DXA results including TBS, means were adjusted by for age and BMI and compared using the corresponding F-test. Statistical significance was set at $p<0.05$. Those variables that showed independent association with poverty were then entered in a multiple logistic regression analysis. A selection was carried out using a retrospective method based on Akaike's information criterion. Data were analyzed with the SPSS statistical program (19.0, SPSS, Chicago, Il).

Results

Table 1 shows the baseline characteristics of the population studied. Women were classified according to their socioeconomic status into two groups: Group I (Poverty) was composed of 354 women with low socioeconomic status, whereas 408 women were classified not in poverty (Group II). Women in poverty were older, heavier and shorter than those not in poverty. Because of this, all the comparisons were performed after adjusting by age and BMI. There was a similar distribution of some lifestyles risk factors for osteoporosis. Women in poverty showed a lower consumption of tobacco (20,3% vs. 39,5%) and a lower use of hormonal replacement therapy (HRT) than women not in poverty (11% vs 19,4%). On the other hand, women in poverty showed a higher prevalence of obesity (45,5% vs. 22,3%), type 2 diabetes mellitus (23.7% vs. 8.8%), arterial hypertension (60.2% vs 38.2%), use of hypnotics (76,3% vs 66,2%), and low physical activity (78.1% vs 60.5%). Actual calcium intake and the prevalence of falls were similar in both groups.

Table 2 shows Quantitative ultrasound, DXA and TBS measurements in postmenopausal women with poverty and non-poverty. Comparison was made after adjusting by age and body mass index (BMI). All the parameters showed statistically significant lower values in postmenopausal women with poverty compared to those with non-poverty. This occurred with BUA, QUI (QUS

Table 1. Basal characteristics of the study population according to their economic status.

	Poverty		
	Group I. Yes	Group II. No	P value
	n= 354	n= 408	
Age (years)	66.8 ± 9.7	64.5 ± 10	0.001
Weight (Kg)	70.8 ± 14.1	65.1 ± 11.6	<0.001
Height (cm)	154.7 ± 6.8	156.9 ± 6.7	<0.001
Body mass index (Kg/m^2)	29.5 ± 5.4	26.4 ± 4.5	<0.001
Actual calcium intake (mg/day)	735.5 ± 355.4	742.6 ± 331.8	0.770*
Living in rural areas (%)	30.5	14.2	<0.001*
Tobacco consumption (%)	20.3	39.5	<0.001*
HRT use (%)	11	19.4	<0.001*
Thiazide use (%)	16.4	13	0.650*
Low physical activity (%)	78.1	60.5	0.001*
Obesity (IMC ≥ 30 Kg/m^2) (%)	45.5	22.3	<0.001**
Diabetes Mellitus (%)	23.7	8.8	<0.001*
Hypertension (%)	60.2	38.2	<0.001*
Hipnotics use (%)	76.3	66.2	0.003*
Falls (%)	42.7	34.3	0.096*

**Adjusted by age and body mass index (BMI)*
*** Adjusted only by age*

Table 2. Comparisons after adjusting by age and body mass index (BMI).

	Poverty		
	Group I. Yes	Group II. No	
	n= 354	n= 408	P value
QUS			
BUA (db/mgHz)	58.5 ± 17.4	60.5 ± 17	0.023
Tscore	-1.2 ± 1.1	-1.1 ± 1.1	0.023
SOS (m/s)	1509.4 ± 101.8	1509.8 ± 117.8	0.686
Tscore	-1.8 ± 3.3	-1.8 ± 3.8	0.686
QUI	74.3 ± 18	77.5 ± 19.3	0.018
Tscore	-1.6 ± 1	-1.4 ± 1	0.018
TBS (g/cm^2)	1.227 ± 0.1	1.258 ± 0.1	0.014
Tscore	-2.7 ± 1.4	-2.3 ± 1.9	0.014
DXA			
L2L4 (g/cm^2)	0.839 ± 0.17	0.846 ± 0.16	0.003
Tscore	-1.6 ± 1.4	-1.5 ± 1.3	0.003
Femoral neck (g/cm^2)	0.666 ± 0.12	0.661 ± 0.13	0.103
Tscore	-1.52 ± 1	-1.56 ± 1	0.103
Total hip (g/cm^2)	0.798 ± 0.15	0.783 ± 0.14	0.030
Tscore	-0.36 ± 1.1	-0.47 ± 1.1	0.030

TBS: Trabecular Bone Score

parameters), DXA measurements (at the lumbar spine -L2-L4 and total hip) and finally with TBS measured at the lumbar spine. There were no statistically significant differences in SOS and femoral.

Table 3 shows the prevalence of fragility fractures. Women with poverty showed a higher prevalence of all fragility fractures (considered all of them together) but no statistically significant differences were found when the different types of fractures were studied individually: vertebral, forearm, humerus, tibia, ribs and hip.

Discussion

Our study shows that poor postmenopausal women have reduced bone quality compared to those who are not poor, estimating bone quality by two different methods: TBS and calcaneal ultrasound.

Table 3. Prevalence of fragility fractures. P values were calculated after adjusting by age and BMI.

	Poverty		
	Group I. Yes	Group II. No	
	n= 354	n= 408	P value
Fragility fractures Yes (%)	41.8	31.6	0.039
Vertebral fractures Yes (%)	14.1	12	0.098
Colles fracture Yes (%)	11.6	9.6	0.120
Humerus fracture Yes (%)	4.8	5.1	0.381
Tibia fractures Yes (%)	4.5	5.2	0.064
Rib fractures Yes (%)	1.4	2.9	0.683
Hip fracture Yes (%)	5.1	4.2	0.067

This leads to a higher prevalence of fragility fractures. In a previous study conducted by our working group more than 10 years ago, we published the association between poverty and osteoporosis [20]. However, in that study we were only able to establish the existence of a lower bone mineral density without studying other bone components related to bone strength, such as microarchitecture and bone quality.

Over the past decade, a new way to assess bone microarchitecture has emerged, called the trabecular bone score (TBS) [32-34]. This novel method, which is entirely noninvasive and, in fact, requires no further patient testing, has been repeatedly shown to be a BMD-independent predictor of skeletal strength and fracture risk. It consists of gray-scale textural analysis of anteroposterior LS-DXA images previously obtained for BMD assessments. It also, by assessing the micro-architectural texture of trabecular bone, contributes to the evaluation of bone strength, thereby aiding in the diagnosis of osteoporosis and the prediction of future osteoporotic fractures [10,12,32,35-37]. Besides being non-invasive and efficient for use, since no additional patient visits are required, the fact that TBS utilizes previously obtained DXA images has allowed for the rapid generation of an extensive body of empirical data. In the largest published study assessing TBS and considering 29,407 postmenopausal women in the Canadian province of Manitoba, there were 1,668 incident major osteoporotic fractures, including 439 vertebral fractures and 293 hip fractures over the 5 years of follow-up. BMD at lumbar spine and TBS predicted fractures equally well, and the combination of both performed better than either individually [38]. Moreover, TBS appeared to enhance fracture risk prediction in those women with BMD in the normal or osteopenic range, but not in those women in the osteoporotic BMD range [39]. On the other hand, QUS of the heel has been proposed as a screening tool to evaluate the bone status and risk of osteoporotic fragility fractures. QUS appears to be a valuable method for the assessment of osteoporotic fracture risk [40], but assessing other aspects of bone, apparently more closely related to bone quality [7,15,41,42].

The poor postmenopausal women in our study are older, heavier and shorter (and consequently higher BMI) than those who are not poor. They also have more detrimental lifestyles, as they are more sedentary and also have a higher prevalence of a number of diseases such as hypertension, obesity, type 2 diabetes mellitus, which has been reported elsewhere [43-46]. Some of these diseases, in turn, have been described as possible risk factors for the appearance of osteoporosis or fragility fractures [1,4].

Table 2 shows the densitometric values of both BMD and TBS as well as the ultrasonographic parameters. It can be seen that poor women have lower values for BMD in both the lumbar spine and the proximal femoral extremity, as well as for TBS and QUS parameters, with the exception of SOS, which, curiously, did not show statistically significant differences between poor and non-poor women. It was therefore predictable to find a higher prevalence of fragility fractures among poor postmenopausal women compared to non-poor women, but this only occurred when we grouped all fragility fractures together (p=0.039) but was not observed individually for each of the different fracture types, probably due to the limited number of fractures collected when separated by group.

A similar 2020 study to ours was conducted by Olmos *et al.* in Cantabria, in the Camargo cohort. In this study, they included 1,450 postmenopausal women aged 44-94 years and found that 11% of the women had a degraded microarchitecture. They found, as we did, an association between TBS and QUS, although it was weak [47].

A limitation of this study is that it does not determine what has come first, the poverty of these women or their poor health condition, making it so they can't work to provide for themselves. Future studies should examine this issue

There are two more limitations to this study: Firstly, it is a cross-sectional study in which only prevalent osteoporotic fractures or metabolic syndrome prevalence was analyzed; thus, prospective studies are necessary to confirm the results. Secondly, the study was conducted in a relatively small sample, not randomly selected from the Canarian population. However, we consider that our sample was representative of the population, because it was composed of subjects who agreed to participate in several epidemiological studies and BMD values obtained at different age groups did not differ from reference values published for the Canarian and Spanish population [28,48,49].

In conclusion, in this study we have been able to observe that among postmenopausal women with poverty a higher prevalence of all type of fragility fractures: vertebral, distal radius, humerus, tibia and hip fractures. Compared to non-poor postmenopausal women, these poor patients, in addition to lower bone mineral density values at both the lumbar spine and proximal femoral extremity, have lower TBS and QUS values, which have been linked as indicators of bone microarchitecture, in the case of TBS, and empirically of bone quality, in the case of QUS.

Conflict of Interest

The authors declare no conflict of interest.

Contributors

Marlene García Quintana, Mª Jesús Gómez de Tejada-Romero and Manuel Sosa-Henríquez were involved in design of the general concept, development of the study, acquisition of data, analysis and interpretation of data, drafting the article and revising it content, discussion. Pino Quintana-Montesdeoca was involved in the statistical study, analysis and interpretation of data, drafting the article and revising it content, discussion. Diego Hernández-Hernández was involved in the design of the general concept, analysis and interpretation of the data, drafting the article and revising its content and discussion.

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Ethical Approval

The study "Association of Poverty with Higher Risk of Fragility Fractures in Postmenopausal Caucasian Spanish Women" was approved".

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